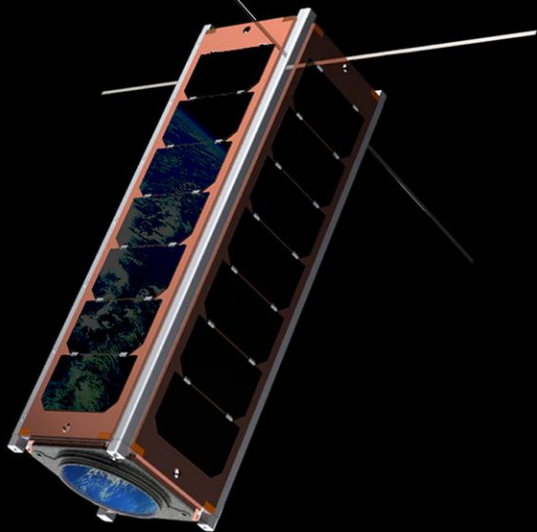


National Aeronautics and Space Administration



Tactically Extensible and Modular Communications – X-Band

TEMCOM-X



Dr. William Herbert Sims

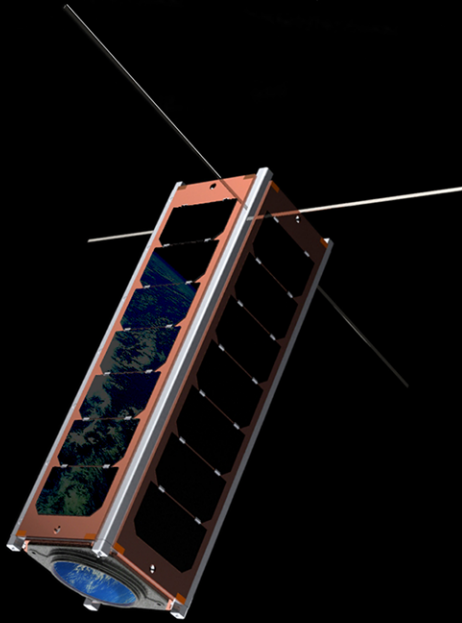
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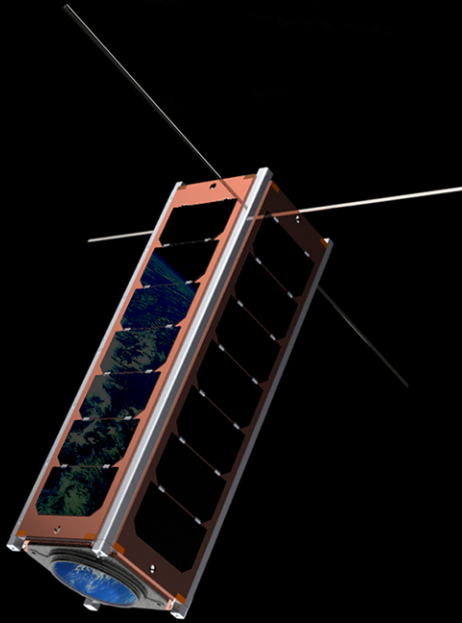
Abstract



- This paper will discuss a CubeSat size (3U) telemetry system concept being developed at Marshall Space Flight Center (MSFC) in cooperation with the U.S. Department of the Army and Dynetics Corporation.
- This telemetry system incorporates efficient, high-bandwidth communications by developing flight-ready, low-cost, Proto-flight software defined radio (SDR) and Electronically Steerable Patch Array (ESPA) antenna subsystems for use on platforms as small as CubeSats and unmanned aircraft systems (UASs).
- Higher bandwidth capacity will enable high-volume, low error-rate data transfer to and from tactical forces or sensors operating in austere locations (e.g., direct imagery download, unattended ground sensor data exfiltration, interlink communications).



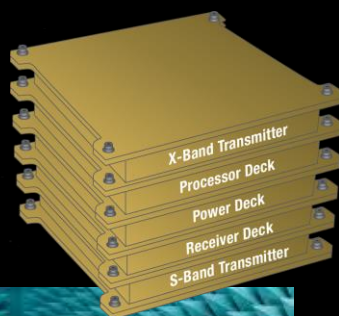
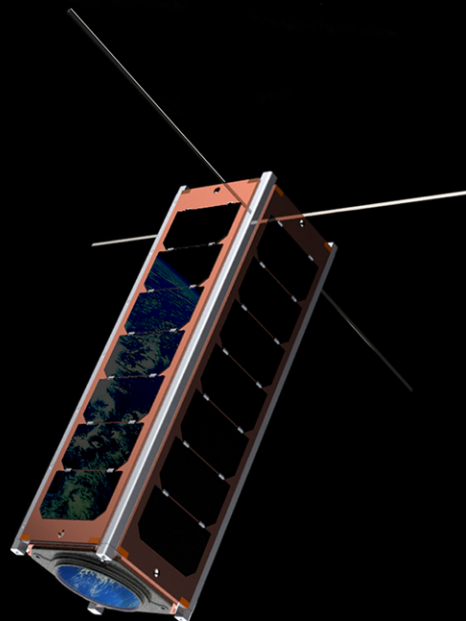
Introduction



- This paper provides information on the Marshall Space Flight Center (MSFC) SDR Low-Cost Transponder as well as the Army/Dynetics Electronically Steerable Phased Array - X-Band (ESPA-X)
- The SDR, called PULSAR – Programmable Ultra Lightweight System Adaptable Radio – as well as the ESPA-X can be incorporated into orbital and suborbital platforms.
- In doing so, Tactically Extensible and Modular Communications - X-Band (TEMCOM-X) will allow project/programs to perform remote commanding capabilities, as well as real-time payload(s) and science instruments telemetry.
- The leap ahead technology is the low-cost space / high-altitude qualified reconfigurable SDR transponder for simultaneous X-band transmit and receive communications at a minimum of 110 Mbps with very low bit error rates.



Technical approach



- The proposed TEMCOM-X Project leverages the lessons learned during the PULSAR telemetry system (First Generation) development, which used NASA funds from FY2012-13.
- The PULSAR base design has three to four selectable decks – power deck, processor deck, X-Band receiver deck, and X-Band telemetry transmitter deck. The application determines the configuration, thus the number of decks used.
- Exemplifying flexibility, PULSAR will transmit using Low Density Parity Check (LDPC, rate 7/8), Reed-Solomon (223/255), or convolutional (Rate $\frac{1}{2}$) Forward Error Correction (FEC) based on mission requirements.
- The antenna array (front-end) will incorporate a planar design consisting of multiple board layers with integrated array circuitry to reduce the array depth.



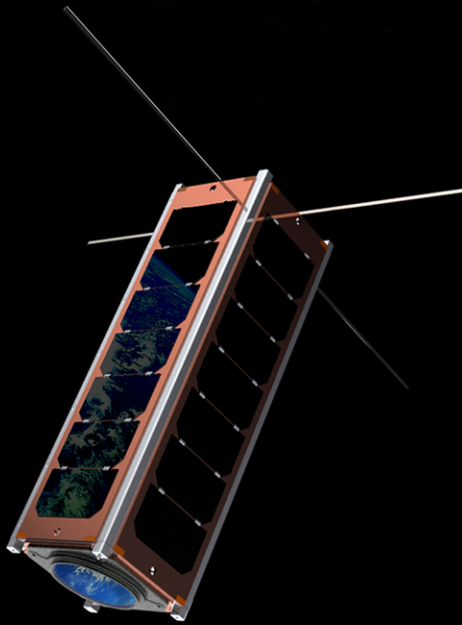
Performance



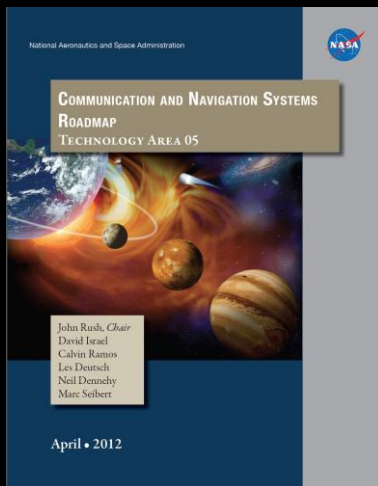
- The system contains sufficient RF link capacity to achieve the desired performance while maintaining the goal Bit Error Probability (BEP) assuming that the design goal gain (19.76dBi) can be met.

| | Uplink | | Downlink | |
|------------|------------------------|---------------------|-----------------------|--------------------|
| Frequency | 8.2GHz | | 8.2GHz | |
| P_T | 50W | 47dBm | 1W | 30dBm |
| $L_{C(T)}$ | 1dB | | 1dB | |
| G_T | 43.9dBi ¹ | | 19.76dBi ² | |
| L_P | 2448km ³ | 178.5dB | 2448km ³ | 178.5dB |
| L_M | 0dB | | 0dB | |
| L_{Pol} | 0.25dB | | 0.25dB | |
| L_A | 1.0dB | | 1.0dB | |
| G/T | -4.91dB/K ⁴ | | 22.5dB/K ¹ | |
| Data Rate | 150Mbps | | 150Mbps | |
| kB | -116.84dB | | -116.84 | |
| SNR | 22.08dB | | 8.35dB | |
| Threshold | No FEC | 12.0dB ⁵ | FEC | 5.0dB ⁶ |
| Margin | +10.08dB | | +3.35dB | |

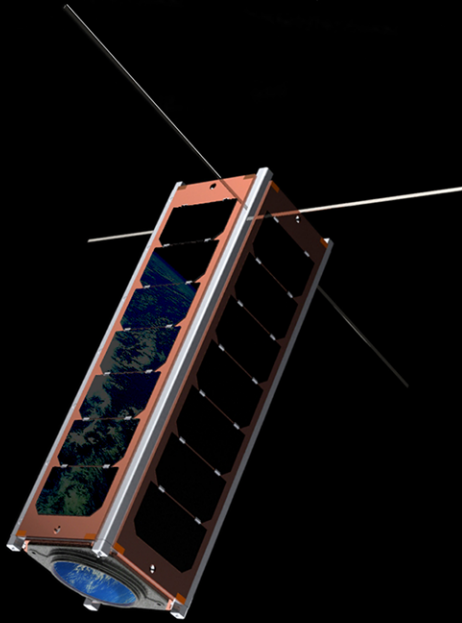
Alignment



- NASA is called, at the direction of the President and Congress, to maintain an enterprise of technology that aligns with missions and contributes to the Nation's innovative economy.
- NASA has been and should be at the forefront of scientific and technological innovation.
- In response to these calls, NASA generated a plan (NASA Strategic Space Technology Investment Plan) to advance technologies and nurture new innovation that will feed into future missions.
- PULSAR aligns primarily with the Technology Area (TA) 5 – Communication & Navigation – but has connections to other TAs in which lightweight structures, power efficiency, and communication reliability and throughput are the focus



ESPA-X

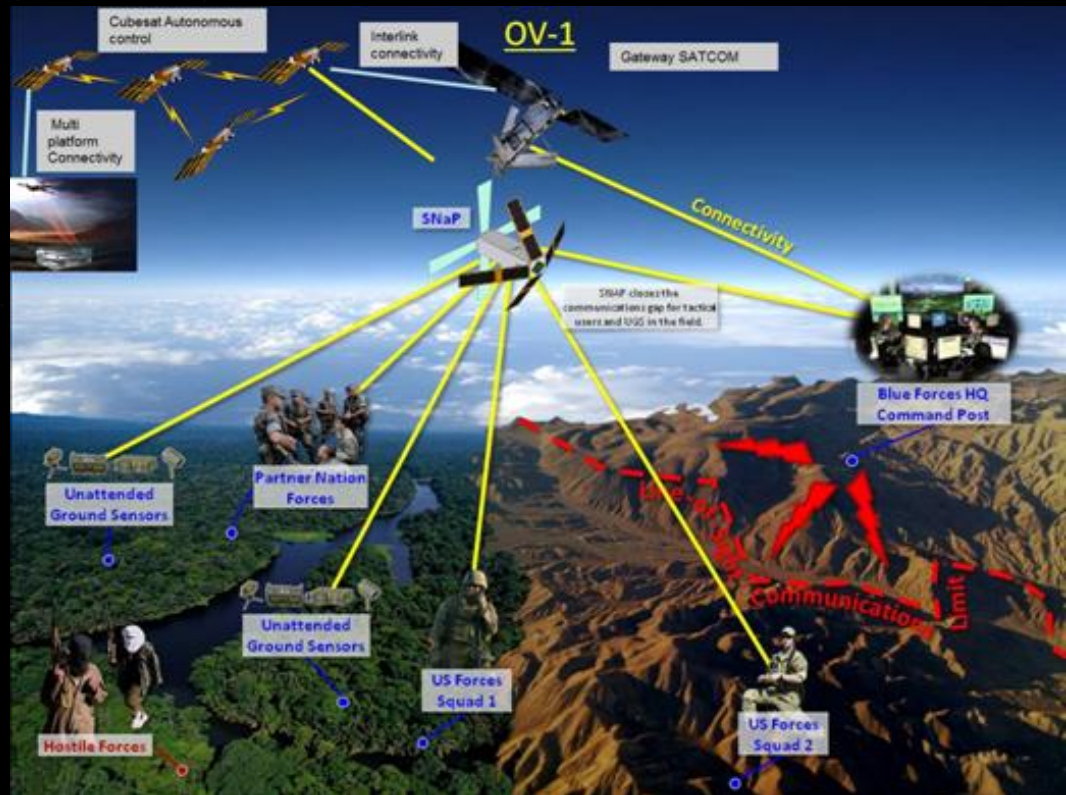


- The current notional design of the espa-x includes a radiating element that is a circularly polarized patch antenna with +8dbi gain with a maximum 11 db return loss (1.78 vswr) in the band of interest.
- The t/r module will transmit in horizontal polarization and receive in vertical.
- The transmit chain is quite simple, with a phase shifter (nominal 7 db loss), an amplifier, and a harmonic reject filter (nominal 1.5 db loss).
- The receive chain gain distribution assumes a 0.4 db loss through the patch antenna and a 1.2 db loss through the front-end bandpass filter.
- The lna's noise figure of 0.6 db is sufficient to insure that the overall transmit chain's noise figure will remain below the required 2.5 db.

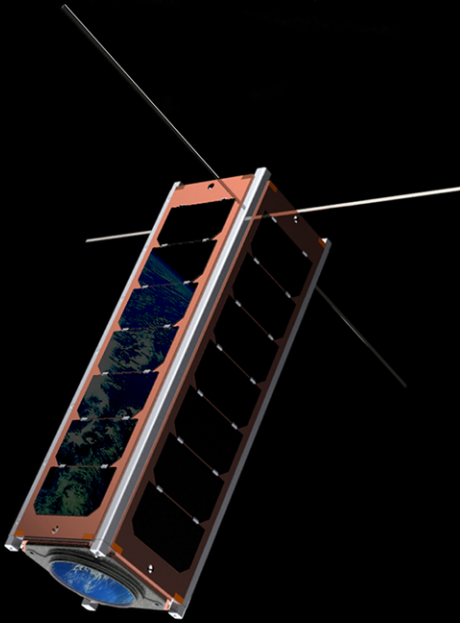
Operational Scenario



- The operational scenario in the graphic shown in the Introduction depicts U.S. and partner nation (PN) small-unit forces operating beyond line-of-sight communications with their command center, and in close proximity to hostile forces.



Operational Scenario



- Encrypted voice between the small units and the command center;
- Relay of imagery, full-motion video (FMV), and other near-real-time data from airborne and orbital sensor platforms to the small units and the command center.
- Multiple beam-forming to provide simultaneous access to multiple locations;
- Provides high rate bandwidth for satellite interlink communications;
- Full duplex transmit and receive for maximizing communication opportunities.



Conclusion

- The TEMCOM X Project is currently in the late formulation stages and has been proposed for planned full implementation to develop and test a protoflight unit of the integrated PULSAR-X and ESPA-X technologies.
- TEMCOM-X leverages existing Marshall Space Flight Center SDR designs and commercially enhanced capabilities.
- Also, TEMCOM-X increases flexibility to implement multiple transponder types by utilizing the same hardware with altered logic – no hardware change required – all of which will eventually be accomplished in orbit.
- TEMCOM-X offers high capability, low cost, transponders to programs of all sizes. The final project outcome will be the introduction of a low-cost CubeSat to SmallSat telemetry system.
- The proposed TEMCOM-X Roadmap includes adaptation into options such as C-Band and Ka-Band. These technologies are planned for continued development.

